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FLOTATION OF CHALCOPYRITE IN CHALCOPYRITE-PYRRHOTITE ORES OF SOUTHERN OREGON

BY

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FLOTATION OF CHALCOPYRITE IN CHALCOPYRITE-PYRRHOTITE ORES OF SOUTHERN OREGON.

By Will H. Coghill.

INTRODUCTION.

In 1916 the Federal Bureau of Mines entered into a cooperative agreement with the Oregon Bureau of Mines and Geology for the purpose of investigating problems bearing on the treatment of low-grade and complex ores. The writer, as consulting metallurgist, was placed in charge of these investigations, and laboratory room for the necessary tests and experiments was provided at the Oregon Agricultural College, at Corvallis. One of the first problems taken up was the possibility of separating chalcopyrite from pyrrhotite and pyrite by flotation.

Chalcopyrite is the copper-bearing mineral at many places in southern Oregon; often it is intimately associated with pyrrhotite and pyrite. In places these two gangue minerals form as much as 75 per cent of the ore, so that the vein is almost wholly sulphides.

Gravitation methods of concentrating the copper-bearing mineral can not be applied, because the gangue sulphides have practically the same density as chalcopyrite. Magnetic separation does not seem practicable—assuming that the gangue sulphides can be made to respond naturally or by a preliminary treatment to an electromagnet—because fine grinding is required to liberate the mineral grains. The methods of concentration now in vogue are hand sorting and jigging, which eliminate some of the siliceous gangue. An inspection of the smelter returns in the possession of mine operators gives the impression that the average grade of ore shipped runs 10 per cent copper.

The experiments on separating the chalcopyrite from the gangue by flotation have been carried through the preliminary laboratory stage with flattering results. As a mill is never considered complete and finished until the ore body is exhausted and the mill has served its purpose, so in this and in other ore-testing experiments there are still undetermined factors. However, in order that those who are interested in the separation of sulphides by flotation may have the results of the laboratory work before them, this preliminary report is published by the Bureau of Mines.

TESTS AND GENERAL DISCUSSION.

The tabulated data in Table 1 show the results of what might be called progress tests, or those in which the results were similar to those of successful practice. Many random tests were made to find the nature of disturbing influences and how to meet them, but only a few of these are mentioned.

TABLE 1.—*Results of progress tests on flotation of chalcopyrite-pyrrhotite ores of southern Oregon.*

[The samples used weighed 1 to 16 pounds and carried 1.13 per cent to 3.2 per cent copper; ratio of concentration ranged from 8:1 to 12:1.]

Sample No.	Name of mine.	Through 200-mesh.	Grade of tailings.	
			Copper in tailings.	Copper in tailings, percentage of total copper content of ore.
		Per cent.	*Per cent.*	
1	Waldo	54.0	0.45	7.2
2	.....do	74.6	.70	20.7
3	.....do	91.0	.30	6.1
4	.....do	92.0	.50	13.0
5	Morrison	44.0	.12	6.3
6	.....do	97.7	.12	5.0
7	Rowley	82.0	.25	8.6
8	.....do	82.2	.20	6.2
9	Queen of Bronze	64.5	.55	....
10	.....do	(?)	.30	23.4
11	.....do	(?)	.26	16.7
12	.....do	(?)	.23	8.1
13	.....do	95.5	.55	24.5
14	.....do	94.5	.50	20.3
15	.....do	91.4	.35	15.1
16	.....do	92.0	.90	29.2
17	.....do	77.5	.70	16.6
18	.....do	99.0	.60	16.1

All the samples were fresh and unoxidized except Nos. 16, 17, and 18. These three contained some malachite and azurite; this accounts for the tailings being higher grade than the average.

Several of the progress tests were made to conform to the tentative flow sheet (fig. 1). The results of one which was made in cooperation with D. C. Morris, representing the American Exploration Co., of Grants Pass, are given in Table 2. This sample was crushed excessively fine. It is likely that a fineness of 75 per cent through 200-mesh would have been satisfactory. Callow cells were used, but the Minerals-Separation type of machines seemed to give equally good results.

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TABLE 2.—*Products of flotation test of Queen of Bronze ore in Callow cells.*

[Feed assayed 3.0 per cent copper; sample crushed to 99 per cent through 200-mesh; contained oxidized copper.]

Sample No.	Products.	Weight of product, grams.	Percentage of total weight.	Copper in product, per cent.	Grams of copper on 100-gram basis.	Per cent of total copper.
54	Concentrate	450	6.0	28.3	1.70	58.5
63	Tailing from middling cell	925	12.3	3.3	.41	14.1
65	Tailing from cleaner	227	3.0	11.0	.33	11.3
61	Tailing	5,940	78.7	6	.47	16.1
		[a] 7,542	100.0	....	2.91	100.0

[a] 7,542 grams=16.6 pounds.

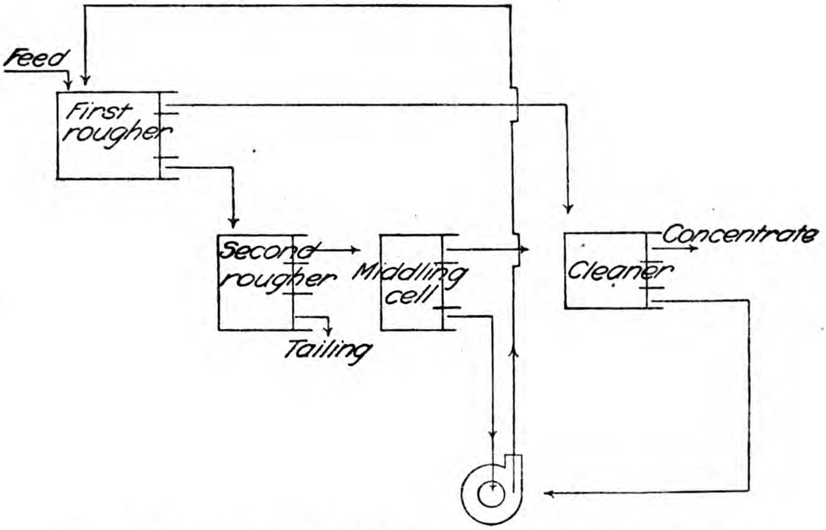

FIGURE 1.—Tentative flow sheet for chalcopyrite-pyrrhotite ores of southern Oregon.

As the work was done with the intermittent type of machines, there were necessarily middling products—Nos. 63 and 65 in Table 2—that have to be disposed of by approximation, as shown below:

METHOD OF APPROXIMATING RESULTS.

From Table 2 the milled products would appear, on a 100-gram basis, to be about as follows:

PERCENTAGE OF RECOVERY.

Nos. 63 and 65 containing $12.3+3.0=15.3$ grams of pulp would produce a tailing running 1 per cent copper.

(*a*) Then $15.3\times\ 0.01=0.15$ gram copper lost.

This loss added to that from No. 61 shows a total of $0.15+0.47=0.62$ gram copper lost, or $0.62\div2.91=21.3$ per cent of the total copper is lost. Hence the recovery is 78.7 per cent.

RATIO OF CONCENTRATION.

These two middling products contain 0.41 + 0.33 = 0.74 grams of copper.

By (*a*) 0.15 gram is lost.

(*b*) The recovery from them is, therefore, 0.74 − 0.15 = 0.59 gram of copper.

(*c*) Assume that this 0.59 gram of copper is in a concentrate running 25 per cent copper. There would be, therefore, 0.59 × 4 = 2.36 grams of concentrate.

(*d*) The total concentrate would then amount to 6.0 (from No. 54) + 2.36 (from *c*) = 8.36 grams concentrate.

This means a final concentration of 100 into 8.36 or 12 into 1.

GRADE OF CONCENTRATE.

8.36 grams (*d*) of concentrate contains 1.70 (No. 54) + 0.59 (*b*) = 2.29 grams of copper; 2.29 ÷ 8.36 = 27.4 per cent copper in concentrate.

COMMENT ON METHOD.

This method of approximation, applied to the tests from samples 1 to 15, inclusive (Table 1), would show an extraction of 90 per cent with an equally high-grade concentrate, except where, as shown by grab samples of the overflow, the test was stopped too soon. The reader should note in regard to the tests shown in Table 2 that only 15.3 per cent of the charge entered the closed circuit for retreatment. This quantity, although small when compared with average practice, is excessive for these ores; it was great in these tests because the tests were prolonged in the effort to float the oxidized copper. The freedom with which the fresh chalcopyrite floats is remarkable. At times there is also a striking play of brassy colors on the overflow.

COLOR NOT A TRUE INDICATOR OF GRADE OF FROTH.

This reference to color introduces a fertile subject for scientific discussion but it must be treated briefly here. The first impression was that the color was a true indicator of the grade of the froth, but later work showed that it was not. Sometimes the Minerals-Separation type of machine gave a richer looking froth than the Callow type, when analysis showed it to be of lower grade. When the pulps are of equal densities, the Minerals-Separation machine gives, without fail, a brassier froth than the Callow. This seems natural because the Minerals-Separation machine makes less froth where the bubbles have had more opportunity to gather the chalcopyrite. The burden of chalcopyrite is therefore heavier and more evident than in a Callow machine where the great number of bubbles—some of them doubtless barren—dart to the surface and form a voluminous froth. The heavy

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burden of nonwetted mineral carried by the froth stabilizes it by the "screw-back" effect that the author has discussed in a recent paper.[a]

The Callow froth showed a better color on the concave upward surface than on the convex; that is, in the depressions. Although it is true that the weight of the mineral grains should be considered as a factor in causing them to slip down the surface to the lowest point and thus increase the burden there, the reader should note also that the resultant of the molecular forces points in that direction. The nonwetted mineral particles (on the upper surface) would therefore be expected to slip down the "meniscus," whereas the tendency of molecular forces would be to pull the wetted particles to the highest points, resulting in segregation. The relation of the component forces has been outlined in a paper in the Colorado School of Mines Magazine.[b]

GOLD RECOVERY.

The ores assay about $2 a ton in gold. Hand-sorting a Queen of Bronze sample and assaying revealed that about 95 per cent of this gold is in the chalcopyrite. Unfortunately the flotation concentrate contains too small a proportion of the gold. It is likely that the gold is embedded in the cleavage planes of the chalcopyrite and is released on crushing. The gold in the tailings amalgamated freely in bottle amalgamation tests, proving it to be in the metallic state.

OIL USED.

Only one oil was tried. It was selected from a stock of 22 oils on account of its desirable physical properties. The surface tension effect of these oils had been determined and plotted by E. H. Miller, of the Bureau of Mines, and the one used was found to give a steeper surface tension curve than any other oil in stock. This was desirable because it was thought that a froth with a slightly variable surface tension would, with the solids present, be sufficiently stable. Whether the other oils would have proved satisfactory was not determined, as the oil mentioned gave excellent results. Its miscibility is an important characteristic.

Only once, and then by accident, was the ore ground in the presence of an insoluble oil. The insoluble oil acted as a collector on all the sulphides present and spoiled the differential separation sought. The overflow carried only 5 per cent copper, whereas 30 per cent copper in the first overflow was desirable and expected when the pulp carries 2½ per cent.

As already stated, the oil used reduces surface tension. It seems strange, in view of all that has been written about surface tension, that there are no published data on absolute values of surface tension of mill solutions. In the course of these experiments several determinations were made by the drop-weight method. One determination gave: Surface tension of overflow 65.9, of underflow, 69.8. This result is in accord with tests made to prove adsorption, as given in text books on colloid chemistry. The quantity of oil necessary is minute, 0.1 pound per ton of ore being ample. The oil was added to the charge in the cell, and the overflow could be drawn after an interval of a few seconds. Neutral water was used.

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[a] Rickard, T. A., and Ralston, O. C., Flotation, 1917, p. 125.

[b] Coghill, W. H., Natural laws in flotation, Colorado School of Mines Mag., vol. 7, 1917, p. 1.

PRECAUTIONS TO BE OBSERVED IN USING PROCESS.

The process is simple when two "Don'ts" are observed.

Don't grind in the presence of an insoluble oil; use it cautiously in any event.

Don't grind samples in a disk pulverizer, and if the use of a ball mill instead of a pebble mill is contemplated, make careful tests to see whether the iron surfaces of the balls have an injurious effect. This is especially interesting in connection with the statements of Zachert [a] and Gahl [b] showing that the use of iron balls has a beneficial effect.

In the experiments described in this paper no apparatus was available for determining the effect of grinding with iron balls in a ball mill, but it was proved conclusively that, for the flow sheet used, the use of the disk pulverizer is not only objectionable but should be avoided for either wet or dry crushing. The same conclusion applies to a "made-up" ore containing chalcopyrite. Two comparative runs were made. Each sample consisted of pulp that had been prepared for cyanide tests, and 30 grams of chalcopyrite. The copper mineral in one was prepared in the disk machine; in the other it was ground to the same degree of fineness in a porcelain mortar. Table 3 shows the relative floatability. The mineral prepared in the mortar overflowed much more freely and gave a higher grade product.

TABLE 3.—*Results of disk and mortar grinding.*

Method of preparing ore.	Overflow.	Copper in overflow.	
		Per cent.	Grams.
	Grams.		
Disk	10	14.0	1.4
Mortar	24	16.2	3.9

These results show that the disk pulverizer should not be used until proved harmless.

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[a] Zachert, Victor, Beneficial effect of grinding with steel balls in flotation: Min. and Sci. Press, vol. 114, May 12, 1917, p. 663.

[b] Gahl, Rudolf, History of the flotation process at Inspiration: Bull. Am. Inst. Min. Eng., No. 117, September, 1916, p. 1656.

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